



# Missouri Department of Natural Resources

## **Biological Assessment**

### **Crooked Creek Crawford County, Missouri**

**2008-2009**

Prepared for:

Missouri Department of Natural Resources  
Division of Environmental Quality  
Water Protection Program

Prepared by:

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## **1.0 Introduction**

At the request of the Missouri Department of Natural Resources (**MDNR**) Water Protection Program (**WPP**), the Environmental Services Program (**ESP**) Water Quality Monitoring Section (**WQMS**) conducted a macroinvertebrate bioassessment of Crooked Creek in Crawford County, Missouri. The 3.5-mile Class P section of Crooked Creek begins approximately 1.7 miles southwest of Viburnum in southeastern Crawford County and flows west-northwest to its confluence with Huzzah Creek approximately 1.5 miles south of Dillard. The Department's Water Pollution Control Branch placed this classified portion of Crooked Creek on the 303(d) list for cadmium and lead based on water quality samples collected from 2002 to 2007. A previous macroinvertebrate study conducted by the Environmental Services Program was determined to be inconclusive due to a lack of sufficient data. The goal of this study is to evaluate the listed segment of Crooked Creek for support of the designated use of aquatic life protection. If impairment is not demonstrated, rationale will be provided for removing the associated reach/reaches from the 303(d) list.

## **1.1 Purpose**

The 3.5-mile Class P section of Crooked Creek is listed on the 2004/2006 Missouri 303(d) list for cadmium and lead. The objective of this study is to determine if aquatic macroinvertebrate life is impaired in the listed section of Crooked Creek. This study will characterize the macroinvertebrate communities in Crooked Creek at two stations within the 3.5 mile 303(d) listed section to determine if the stream is biologically impaired and if so, identify potential stressors.

## **1.2 Objectives**

- 1) Characterize the physicochemical characteristics of Crooked Creek.
- 2) Characterize the habitat characteristics of Crooked Creek.
- 3) Determine if the macroinvertebrate community of Crooked Creek is affected by pollution from metals.

## **1.3 Tasks**

- 1) Conduct physicochemical monitoring of Crooked Creek.
- 2) Conduct a habitat assessment of Crooked Creek.
- 3) Conduct a bioassessment of the macroinvertebrate community of Crooked Creek.

## **1.4 Null Hypotheses**

- 1) Macroinvertebrate assemblages and habitat will not substantially differ between Crooked Creek stream segments.
- 2) Macroinvertebrate assemblages will not substantially differ between Crooked Creek and suitable reference streams.
- 3) Habitat will not substantially differ between Crooked Creek and suitable reference streams.

## **2.0 Methods**

The Water Quality Monitoring Section of the Missouri Department of Natural Resources, Division of Environmental Quality, Environmental Services Program conducted this project.

Michael D. Irwin, Kenneth B. Lister, and the staff of the Water Quality Monitoring Section conducted the study.

## 2.1 Study Timing

Sampling was conducted during the fall of 2008 and spring of 2009. Fall macroinvertebrate and physicochemical water sampling were conducted on October 1, 2008. Spring macroinvertebrate and physicochemical sampling occurred on April 1, 2009.

## 2.2 Station Descriptions

Two stations were chosen on Crooked Creek. These stations, chosen for accessibility and as representative reaches of stream, are approximately three miles apart. To consolidate effort, five other stations, sampled as candidate references for another concurrent study in the Meramec River watershed, were used for habitat comparisons in place of official biological criteria reference (**BIOREF**) stream stations. **BIOREF** stations were used for biological criteria calculation, macroinvertebrate analysis, and land cover comparisons. See Figure 1 for a map of study stations and Table 1 for study station and reference descriptions.

Figure 1  
Map of Crooked Creek Study Area and Ozark/Meramec EDU

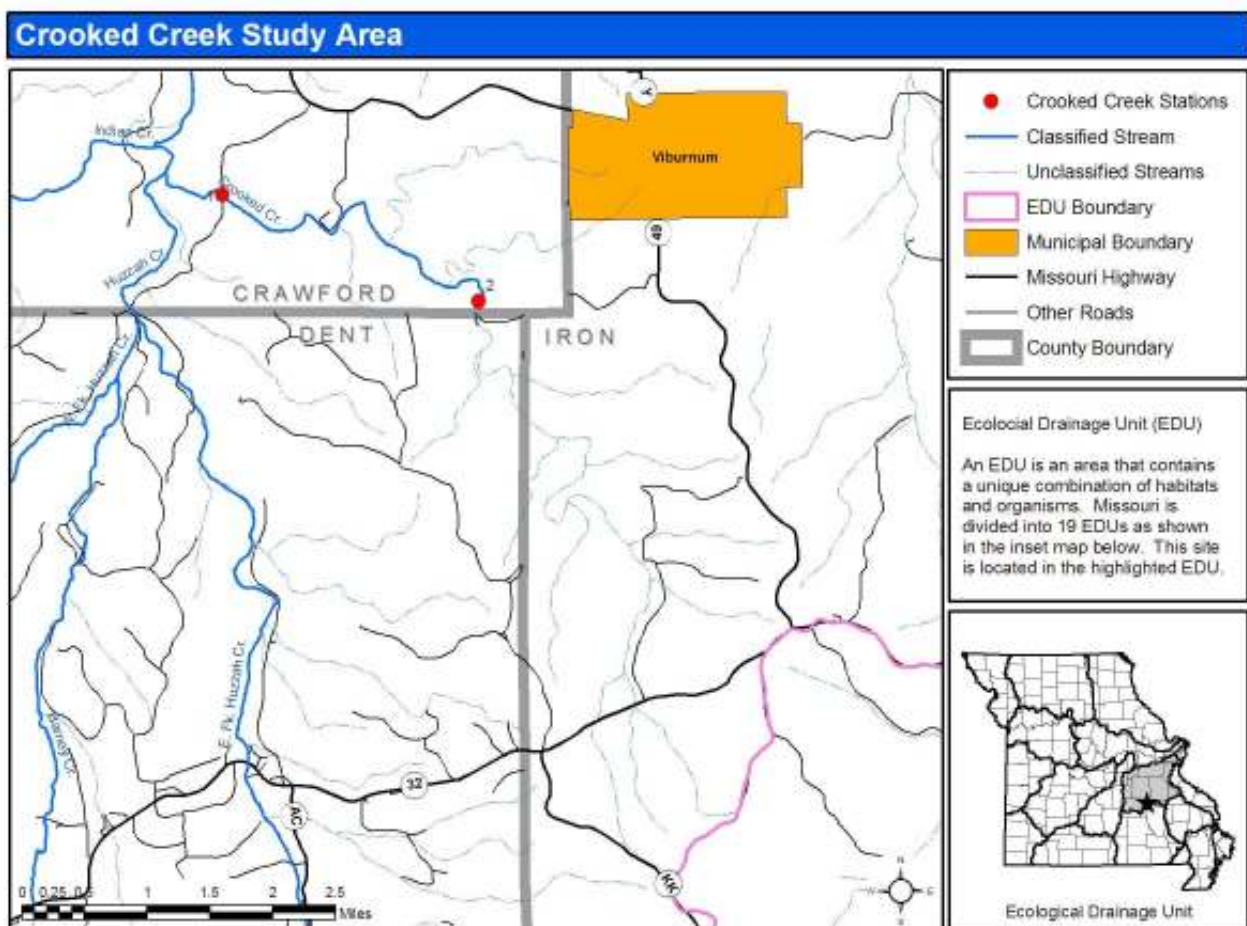


Table 1  
 Location and Descriptive Information for Crooked Creek, Biological Criteria Reference, and  
 Candidate Reference Stations

Station	County	UTM	Description; WBID	Purpose; Class
Crooked Creek 1	Crawford	E659116 N4175206	Upstream of Willhite Rd	Test station
Crooked Creek 2	Crawford	E662234 N4174007	Downstream of Chandler Rd	Test station
Huzzah Creek	Crawford	E660274 N4187479	Downstream of MO Hwy 19	BIOREF; P
Meramec River	Dent	E638353 N4179455	Upstream of Crabtree Rd	BIOREF; P
Brazil Creek	Washington	E672696 N4206120	Downstream USFS Brazil Creek Campground	Candidate Reference; P
Courtois Creek	Iron	E672115 N4175783	Downstream CR80A	Candidate Reference; U
East Fork Huzzah Creek	Dent	E659956 N4164882	Downstream Hwy AC	Candidate Reference; C
West Fork Huzzah Creek	Dent	E653573 N4166719	Downstream MO Hwy 32	Candidate Reference; C
Shoal Creek	Crawford	E663955 N4187505	Along Big Shoal Creek Road	Candidate Reference; P

### 2.2.1 Ecological Drainage Unit

Crooked Creek, BIORREF, and candidate reference stations are all within the same Ecological Drainage Unit (**EDU**; Figure 1). Ecological Drainage Units are delineated drainage units that include all streams and tributaries within a major river basin. Within an EDU, aquatic communities and habitat conditions are expected to be similar between similar-size streams.

### 2.2.2 Land Use

Land cover throughout the entire Ozark/Meramec EDU was compared to the land cover for Crooked Creek by 14-digit Hydrological Unit (**HU**; Table 2). Percent land cover data were derived from Thematic Mapper (TM) satellite data collected between 1991 and 1993 and interpreted by the Missouri Resource Assessment Partnership (MoRAP). The implication of this comparison was that land use within the study area does not interfere with interpretation of the findings; such as comparing streams near cropland and others near forestland.

Table 2  
 Comparison of Land Cover Percentages among 14-Digit Hydrologic Unit Codes (**HUC-14**)  
 for Crooked Creek, Biological Criteria References, and Overall Ozark/Meramec EDU

Stations	HUC-14	Urban	Crop	Grass	Forest
Crooked Creek 1 & 2	07140102030002	1	0	16	81
Meramec River	07140102020005	0	0	18	78
Huzzah Creek	07140102030004	0	0	17	80
Ozark/Meramec EDU	- -	4	1	27	62

### **2.3 Stream Habitat Assessment**

The standardized Stream Habitat Assessment Project Procedure (SHAPP) was followed as described for Riffle/Pool Habitat (MDNR 2003a). Comparisons were made among scores at Crooked Creek stations and the five candidate reference stations. According to the SHAPP, the quality of an aquatic community is based on a stream's ability to support the aquatic community on a given scale. If SHAPP scores were  $\geq 75\%$  of the candidate reference stations, that station was considered comparable to the candidate reference in stream quality. Stream habitat assessments were conducted on all stations in October 2008.

### **2.4 Biological Assessment**

Biological assessment consisted of macroinvertebrate community and physicochemical water analyses. Biological samples were collected at two stations on Crooked Creek in the fall of 2008 and spring of 2009.

#### **2.4.1 Macroinvertebrate Collection and Analyses**

A standardized macroinvertebrate sample collection procedure was followed as described in ESP's Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure (SMSBPP; MDNR 2003b). Metric scores are derived based on taxa presence and community structure in multiple habitats.

The first comparison was of individual metric scores and Macroinvertebrate Stream Condition Index (**MSCI**) scores between stations (MDNR 2002a). Four metrics were used in the evaluation: 1) Taxa Richness (**TR**), 2) Ephemeroptera/ Plecoptera/ Trichoptera Taxa (**EPTT**), 3) Biotic Index (**BI**), and 4) Shannon Diversity Index (**SDI**). Metrics were compared to identify unusual responses or interesting trends between test stations.

An MSCI is a qualitative rank measurement of a stream's aquatic biological integrity (Rabeni et al. 1997). It illustrates impairment of a stream relative to BIOREF streams within the EDU. The MSCI was refined in ESP's Biological Criteria for Wadeable/Perennial Streams for BIOREF streams within each EDU (MDNR 2002a). All metric (TR, EPTT, BI, SDI) scores were compared to the scoring range of the BIOREF and then rank scores (5, 3, 1) were issued to each metric. Ranks for each metric were compiled per station and the total MSCI was completed. A station's MSCI score equates to the biological quality of the aquatic community. For example, an MSCI of 20-16 = fully biologically supporting; 14-10 = partially biologically supporting; and 8-4 = non-supporting of the biological community.

The second analysis of the biological data was an evaluation of the dominant macroinvertebrate families (**DMF**). The predominant families within each station were identified and trends were examined between BIOREF and test stations. Individual taxa lists were also included (Appendix B).

#### **2.4.2 Physicochemical Water Collection and Analyses**

Physicochemical water samples were collected according to MDNR, ESP Standard Operating Procedures (**SOPs**) and Project Procedures (**PPs**) for sampling and analyzing physical and chemical samples. Samples were collected according to MDNR-FSS-001

Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Sampling Considerations (MDNR 2003c). Results are reported for physicochemical water variables in chronological order. Samples were collected and analyses conducted in the fall of 2008 and spring of 2009.

Water quality parameters were measured *in-situ* or collected and returned for analyses at the state environmental laboratory. Temperature (C°) (MDNR2003d), pH (MDNR 2001a), specific conductance (μS) (MDNR 2003e), and dissolved oxygen (mg/L) (MDNR 2002b) were measured in the field. Turbidity (NTU) (MDNR 2005c) was measured and recorded in the ESP, WQMS biology laboratory. The ESP, Chemical Analysis Section (CAS) in Jefferson City, Missouri conducted the analyses for ammonia-nitrogen (mg/L), nitrate+nitrite-nitrogen (mg/L), total nitrogen (mg/L), chloride (mg/L), non-filterable residue (mg/L), and total phosphorus (mg/L).

### **2.4.3 Discharge**

Stream flow was measured using a Marsh-McBirney flowmeter at each station. Velocity and depth measurements were recorded to derive a discharge as cubic feet per second (cfs). Methodology was in accordance with SOP, MDNR-WQMS-113 Flow Measurement in Open Channels (MDNR 2003f).

### **2.5 Quality Control**

Quality control was conducted according to MDNR Standard Operating Procedures and Project Procedures.

### **3.0 Results and Analyses**

The results section includes stream habitat assessments, biological assessments, and physicochemical results. Variables found to have high values or that follow interesting trends are included in each section.

#### **3.1 Stream Habitat Assessment**

Stream habitat assessment (SHAPP) scores were arranged by station to assess the quality of habitat on Crooked Creek (Table 3). According to the Stream Habitat Assessment Project Procedure (SHAPP; MDNR 2003a) a study stream that scores greater than 75 percent of reference stream conditions is considered to have habitat that is capable of fully supporting a similar biological community. Crooked Creek SHAPP scores were greater than 75 percent of all candidate reference stations with the exception of Crooked Creek 1 and West Fork Huzzah Creek. However, both Crooked Creek stations scored greater than 75 percent of the average of all candidate references. Crooked Creek 1 is heavily-grazed pasture land with little to no riparian corridor, but in-stream conditions were relatively good.



Table 3  
Stream Habitat Assessment Scores for Crooked Creek and Candidate Reference Stations

Station	SHAPP Score	Percent of candidate reference average
Crooked Creek 1	125	80
Crooked Creek 2	154	99
Brazil Creek	161	156 candidate reference average
Courtois Creek	146	
West Fork Huzzah Creek	169	
East Fork Huzzah Creek	152	
Shoal Creek	151	

### 3.2 Biological Assessment

Biological assessments consist of macroinvertebrate community and physicochemical water analyses. The primary metrics and MSCI scores were calculated according to the Biological Criteria Development for Wadeable/Perennial Streams of Missouri (MDNR 2002). A summary of MSCI scores for Crooked Creek stations and associated criteria can be found in Table 4. Individual taxa are listed for each station and season in Appendix B.

Table 4  
Biocriteria Metric Scores and MSCI Scores for Crooked Creek

Station/Score	Date	Sample #	TR (Score)	EPTT (Score)	BI (Score)	SDI (Score)	Total Score	Sustainability
<b>Fall 2008</b>								
Score of 5	--	--	>78	>20	<5.9	>3.08	--	Fully Biologically Supporting
Score of 3	--	--	39 - 78	11 - 20	7.9 - 5.9	1.55 - 3.08	--	Partially Biologically Supporting
Score of 1	--	--	<39	<11	>7.9	<1.55	--	Non-Supporting of Biological Community
Crooked Creek 1	10/01/2008	0804115	73 (3)	17 (3)	6.1 (3)	2.86(3)	12	Partially Biologically Supporting
Crooked Creek 2	10/01/2008	0804114	58 (3)	12 (3)	5.9 (3)	2.68 (3)	12	Partially Biologically Supporting
<b>Spring 2009</b>								
Score of 5	--	--	>91	>28	<5.9	>3.32	--	Fully Biologically Supporting
Score of 3	--	--	46 - 91	15 - 28	7.9 - 5.9	1.67 - 3.32	--	Partially Biologically Supporting
Score of 1	--	--	<46	<15	>7.9	<1.67	--	Non-Supporting of Biological Community
Crooked Creek 1	04/01/2009	0930013	70 (3)	18 (3)	5.4 (5)	3.13 (3)	14	Partially Biologically Supporting
Crooked Creek 2	04/01/2009	0930014	69 (3)	17 (3)	6.6 (3)	2.72 (3)	12	Partially Biologically Supporting

#### 3.2.1 Macroinvertebrate Community Analyses

MSCI scores for both stations and both seasons ranged from 12 to 14, resulting in an assignment of partial biological sustainability. With the exception of one spring BI score of 5 for Crooked Creek 1, all other metrics scored 3. This higher BI score may indicate a slight improvement in the downstream reach, but it is not enough to suggest a recovery to full biological sustainability.

Dominant macroinvertebrate orders and families were calculated, and the results can be found in Table 5. This information shows some notable trends. In the fall samples, Ephemeroptera were more common in downstream samples, while Hydracarina and Diptera were more common in upstream samples. Baetidae decreased in upstream samples, while Simuliidae increased. In the spring samples, Diptera were much more common. Plecoptera decreased in upstream samples, while Hydracarina increased. Baetidae and Leuctridae became less common in upstream samples as well.

Table 5  
Dominant Macroinvertebrate Orders (DMO) and Families (DMF)  
as a Percentage of the Total Number of Individuals per Station

Fall 2008				Spring 2009			
Crooked Creek 1		Crooked Creek 2		Crooked Creek 1		Crooked Creek 2	
Order	%	Order	%	Order	%	Order	%
Ephemeroptera	52.7	Ephemeroptera	35.8	Diptera	66.1	Diptera	70.2
Trichoptera	17.0	Diptera	27.3	Ephemeroptera	11.5	Ephemeroptera	17.9
Diptera	16.2	Hydracarina*	11.3	Plecoptera	6.7	Hydracarina*	3.8
Coleoptera	6.7	Trichoptera	11.1	Trichoptera	6.6	Coleoptera	3.0
Odonata	2.0	Coleoptera	9.2	Coleoptera	2.4	Trichoptera	2.1
Family	%	Family	%	Family	%	Family	%
Caeinidae	31.9	Caeinidae	26.7	Chironomidae	59.8	Chironomidae	66.4
Hydropsychidae	14.4	Simuliidae	13.6	Caeinidae	5.9	Caeinidae	15.4
Chironomidae	14.1	Chironomidae	12.7	Baetidae	4.4	Hydracarina*	3.8
Baetidae	13.2	Hydracarina*	11.3	Leuctridae	4.4	Elmidae	2.9
Elmidae	5.0	Hydropsychidae	8.4	Hydropsychidae	4.4	Simuliidae	1.5
		Elmidae	8.4				

\*suborder

Another noteworthy trend is demonstrated by specifically examining a couple of Ephemeroptera taxa between test stations and historical BIOREF data. A summary of this analysis is shown in Table 6, and the significance will be discussed later in this report.

Table 6  
Ephemeroptera Taxa as a Percentage of the Total Number of Individuals per Station Compared to Historical Biological Criteria Reference Data

	Heptageniidae	Isonychidae
Fall Samples		
Crooked Creek 1	0.8	2.0
Crooked Creek 2	0	0.3
Huzzah Creek - range (n=4)	7.9 - 14.3	3.2 - 11.5
Meramec River - range (n=3)	10.6 - 12.8	2.2 - 6.7
Spring Samples		
Crooked Creek 1	<0.1	0
Crooked Creek 2	0	0
Huzzah Creek - range (n=3)	5.6 - 16.1	1.0 - 4.4
Meramec River - range (n=3)	4.6 - 9.2	0.7 - 2.2

Compared to BIOREF stream stations in the same EDU, Heptageniidae and Isonychiidae are much less common in Crooked Creek stations. In addition, except for Isonychiidae in spring samples, these families are less common in the upstream station of Crooked Creek.

### 3.2.2 Physicochemical Water

Physicochemical water data were compared to Missouri's Water Quality Standards (MDNR 2009). A summary of physicochemical data can be found in Table 7.

Table 7  
 Physicochemical Water Variables for Crooked Creek

	Station 1 - Fall 08	Station 2 - Fall 08	Station 1 - Spring 09	Station 2 - Spring 09
Sample #	810014	810013	912014	912013
Date	10/1/2008	10/1/2008	4/1/2009	4/1/2009
Ammonia as N (mg/L)	0.03	0.03	0.03	0.03
Cadmium-Dissolved (µg/L)	<b>1.72*</b>	<b>3.81*</b>	<b>1.25*</b>	<b>2.95*</b>
Calcium-Dissolved (mg/L)	65.1	73.5	36.7	41.0
Chloride (mg/L)	19.30	25.10	5.76	7.13
Copper-Dissolved (µg/L)	3.03	4.40	3.01	3.83
Field Dissolved Oxygen (mg/L)	8.04	9.60	9.24	9.43
Field Flow (cfs)	7.05	7.32	25.70	18.70
Field pH (su)	7.6	7.8	8.4	8.3
Field Specific Conductivity (µS/cm)	1030	1390	606	721
Field Temperature (°C)	17.0	13.5	13.5	15.0
Field Turbidity (NTU)	1.00	1.00	1.46	2.68
Hardness as CaCO <sub>3</sub> (mg/L)	318	353	172	192
Iron-Dissolved (µg/L)	1.57	2.53	11.00	22.70
Lead-Dissolved (µg/L)	0.57	4.41	0.69	2.60
Magnesium-Dissolved (mg/L)	37.7	41.3	19.6	21.8
Nickel-Dissolved (µg/L)	1.49	9.44	2.58	6.66
Nitrate + Nitrite as N (mg/L)	0.13	0.22	0.08	0.09
Non-Filterable Residue (mg/L)	NA	NA	5	5
Sulfate (mg/L)	440	576	168	222
Total Nitrogen (mg/L)	0.14	0.23	0.18	0.25
Total Phosphorus (mg/L)	0.01	0.01	0.01	0.01
Zinc-Dissolved (µg/L)	5.08	20.20	6.81	19.80

\* higher than chronic criterion but lower than acute criterion

Except for dissolved metals, most physicochemical variables were unremarkable. While many of the dissolved metals were likely elevated compared to background levels, dissolved cadmium exceeded Missouri's Water Quality Standard for chronic cadmium (MDNR 2009). No metals exceeded Missouri's acute metals standards. Dissolved metals concentrations were remarkably higher at the upstream Crooked Creek station.

## 4.0 Discussion

While a SHAPP was not completed for one of the BIOREF streams in the same EDU, the high quality of habitat found in the collection of candidate reference streams should be sufficient for SHAPP score comparisons in this study. With the exception of open pasture land at the

downstream station, habitat in Crooked Creek is quite good. The in-stream habitat at both stations on Crooked Creek appeared to be ideal. For this reason, it does not appear that Crooked Creek would be impaired for habitat reasons.

Physicochemical results showed relatively high levels of dissolved metals. In fact, these results also showed dissolved cadmium above the Missouri Water Quality Standard for cadmium (MDNR 2009) for both stations and seasons.

All MSCI scores reflect that both stations of Crooked Creek attain partial biological sustainability. While MSCI scores were similar between the stations, the downstream station scored slightly higher in the spring. While this may suggest some sort of recovery, it is likely partial biological sustainability continues downstream to Huzzah Creek.

Metals can affect aquatic organisms in water, in sediment, or in the food chain (Rainbow, 1996; Maret et al. 2003). Maret et al. (2003) found that some Ephemeroptera taxa are significantly lower in number at streams contaminated by metals versus BIOREF streams. Low abundance of Heptageniidae and Isonychiidae are indicators of metals pollution (Clements et al. 1988, Clements et al. 2000) and these mayflies were absent or less abundant at Crooked Creek than BIOREF streams within the same EDU.

## **5.0 Conclusion**

It is apparent that dissolved metals are having a negative impact on the biota of Crooked Creek in Crawford County, Missouri. Based on dissolved metals data from surface water grab samples taken during this study, dissolved cadmium is a likely culprit.

All objectives and tasks for this study were achieved. Null hypothesis 1 was accepted; macroinvertebrate assemblages and habitat did not substantially differ between Crooked Creek stream segments. Null hypothesis 2, however, was rejected. While habitat did not substantially differ between Crooked Creek and appropriate reference streams, macroinvertebrate assemblages did substantially differ.

## **6.0 Recommendations**

- Studies that identify levels of dissolved metals bioaccumulated in taxa should be conducted periodically.
- Studies to determine specific macroinvertebrate/metal sensitivities, if possible, would be very helpful.
- Crooked Creek should be monitored seasonally for dissolved metals, especially cadmium, at all stations.
- Efforts should be made to identify potential sources of metals into Crooked Creek and action should be taken to reduce these inputs.

## **6.0 Literature Cited**

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**Appendix A**

Missouri Department of Natural Resources Bioassessment Study Plan  
Crooked Creek, Crawford County  
August 15, 2008



Missouri Department of Natural Resources  
Environmental Services Program  
Water Quality Monitoring Section

**Bioassessment Study Plan**  
**Crooked Creek, Crawford County**  
**August 15, 2008**

**Objective**

One 3.5-mile Class P section of Crooked Creek is listed on the 2004/2006 Missouri 303(d) list for cadmium and lead. The objective of this study is to determine if aquatic macroinvertebrate life is impaired in the listed section of Crooked Creek. This study will characterize the macroinvertebrate communities in Crooked Creek at two stations within the 3.5 mile 303(d) listed section to determine if the stream is biologically impaired and if so, identify potential stressors.

**Null Hypotheses**

- 1). Macroinvertebrate communities in Crooked Creek will not differ significantly from macroinvertebrate communities in similar sized reaches of reference streams within the Ozark/Meramec Drainage Unit (EDU).
- 2). Macroinvertebrate communities will not differ significantly between the two longitudinally separate reaches of Crooked Creek.
- 3). Water quality parameters will not differ significantly between the two longitudinally separate reaches of Crooked Creek or with applicable Missouri Water quality Standards.
- 4.) Habitat in Crooked Creek will not differ significantly from habitat in similar sized reaches of reference streams within the Ozark/Meramec Drainage Unit (EDU).
- 5). Habitat will not differ significantly between the two longitudinally separate reaches of Crooked Creek.

**Background**

The 3.5-mile Class P section of Crooked Creek begins approximately 1.7 miles southwest of Viburnum in southeastern Crawford County and flows west-northwest to its confluence with Huzzah Creek approximately 1.5 miles south of Dillard. The Department's Water Pollution Control Branch listed this classified portion of Crooked Creek for cadmium and lead based on water

quality samples collected from 2002 to 2007. A previous macroinvertebrate study conducted by the Environmental Services Program was determined to be inconclusive due to a lack of sufficient data. The goal of this study is to evaluate the listed segment of Crooked Creek for support of the designated use of aquatic life protection. If impairment is not demonstrated, rationale will be provided for removing the associated reach/reaches from the 303(d) list.

### **Study Design**

**General:** Two Crooked Creek stations will be surveyed. For a map of Crooked Creek sampling stations, refer to Attachment A. The station locations are as follows:

- 1) Upstream of Willhite Road, UTM Zone 15 658939E 4175359N
- 2) Downstream of Chandler Road, UTM Zone 15 662224E 4173987N

To assess comparability between sampling stations and reference streams, stream discharge, habitat assessment and water chemistry will be determined during macroinvertebrate surveys. Sampling will be conducted during the fall of 2008 (mid September through mid October) and the spring of 2009 (mid March through mid April).

**Biological Methods:** Macroinvertebrates will be sampled according to methods in the Semi-Quantitative Macroinvertebrate Stream Bioassessment Project Procedure (**SMSBPP**) (MDNR 2003a). Crooked Creek is considered a riffle/pool predominant stream. Therefore, samples will be collected from the following three habitats: flowing water over coarse substrate; depositional substrate (non-flow); and root-mat substrate. Each habitat sample will be a composite of six subsamples.

**Habitat Sampling Methods:** A standardized habitat procedure for riffle/pool stream types will be followed in the Stream Habitat Assessment Project Procedure (**SHAPP**) guidelines (MDNR 2003b).

**Water Quality Sampling Methods:** Samples will be collected per the methods described in the department's standard operating procedures (**SOP**) MDNR-FSS-001 (Required/Recommended Containers, Volumes, Preservatives, Holding Times, and Special Considerations) and MDNR-ESP-002 (Field Sheet and Chain-of-Custody Record). In addition the following field parameters will be measured: temperature [MDNR-FSS-101 (Field Measurement of Water Temperature)]; dissolved oxygen [MDNR-WQMS-103 (Sample Collection and Field Analysis of Dissolved Oxygen Using a Membrane Electrode Meter)]; conductivity [MDNR-FSS-102 (Field Analysis for Specific Conductance)]; and pH [MDNR-FSS-100 (Field Analysis of Water Samples for pH)]. Stream velocity will be

measured at the time of sample collection using a Marsh-McBirney Flo-Mate<sup>™</sup> Model 2000 flow meter. Discharge will be calculated in cubic feet per second using the method in MDNR-WQMS-113 (Flow Measurement in Open Channels). All field meters used to collect water quality parameters are maintained in accordance with MDNR-ESP-213 (Quality Control Procedures for Checking Water Quality Field Instruments).

**Laboratory Methods:** All samples of macroinvertebrates will be processed and identified per MDNR-WQMS-209 (Taxonomic Levels for Macroinvertebrate Identification). Water samples from all sampling stations will be analyzed by the ESP Chemical Analysis Section for dissolved metals (cadmium, copper, iron, lead, nickel, zinc, calcium, and magnesium), hardness, ammonia, nitrogen as NO<sub>2</sub>+NO<sub>3</sub>, total nitrogen, total phosphorus, sulfate, chloride, and turbidity. All turbidity samples will be analyzed per MDNR-WQMS-012 (Analysis of Turbidity Using the Hach 2100P Portable Turbidimeter).

**Data Recording and Analyses:** Macroinvertebrate data will be entered in a Microsoft Access database in accordance with MDNR-WQMS-214 (Quality Control Procedures for Data Processing). Data analysis is automated within the Access database. Four standard metrics are calculated according to the SMSBPP: Total Taxa (TT); Ephemeroptera, Plecoptera, Trichoptera Taxa (EPTT); Biotic Index (BI); and the Shannon Diversity Index (SDI) will be calculated for each reach.

Macroinvertebrate data will be analyzed in two ways. First, a longitudinal comparison between the two Crooked Creek reaches will be performed. Secondly, the data from the Crooked Creek stations will be compared to biological criteria from wadeable/perennial reference streams with similar geology and watershed size classification.

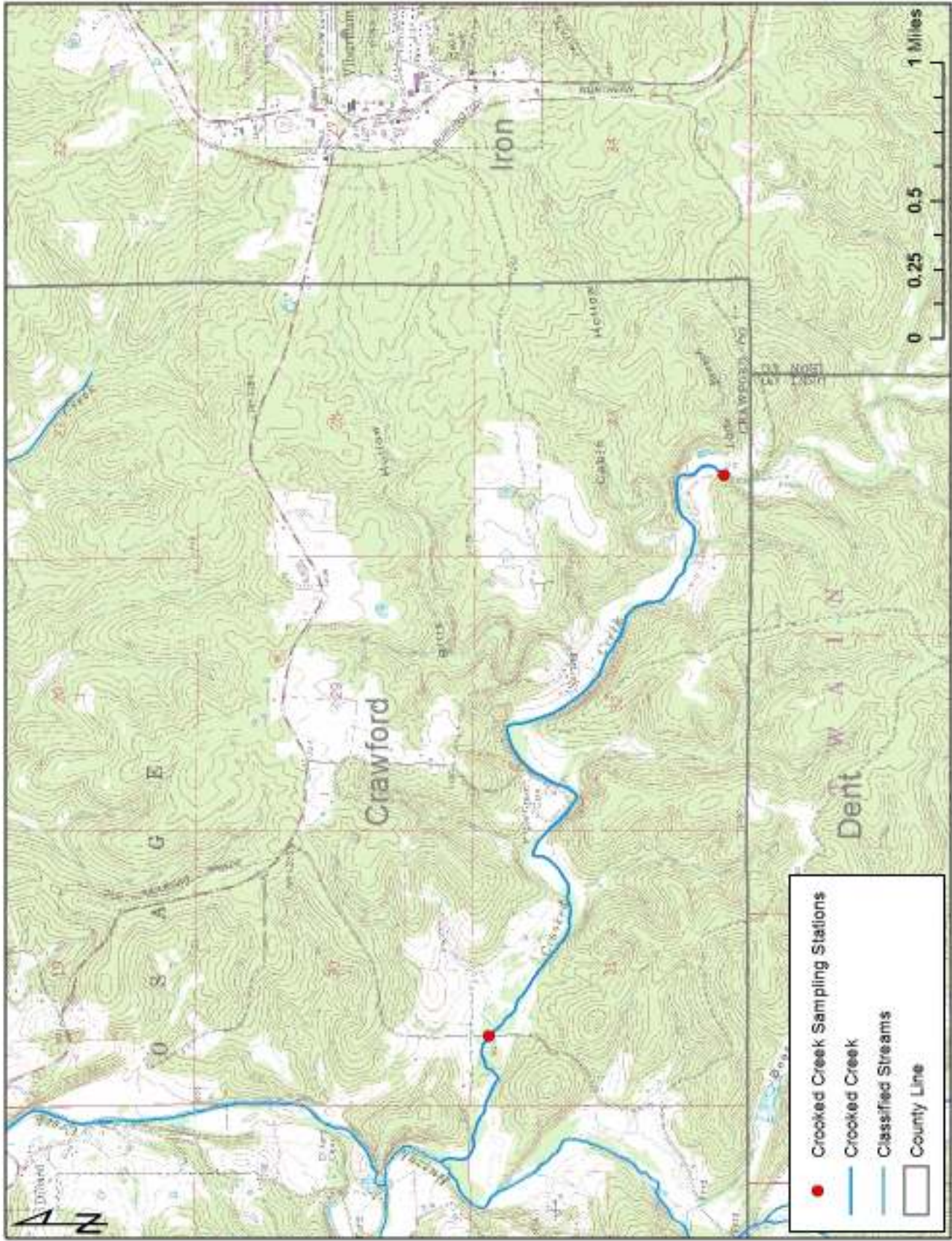
**Data Reporting:** Results of the study will be summarized and interpreted in report format.

**Quality Control:** As stated in the various MDNR Project Procedures and Standard Operating Procedures.

**References:**

Missouri Department of Natural Resources. 2003a. Semi-quantitative Macroinvertebrate Stream Bioassessment Project Procedure. Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 24 pp.

Missouri Department of Natural Resources. 2003b. Stream Habitat Assessment Project Procedure (SHAPP). Missouri Department of Natural Resources, Environmental Services Program, P.O. Box 176, Jefferson City, Missouri 65102. 40 pp.



**Appendix B**  
Macroinvertebrate Bench Sheets for Crooked Creek Stations

**Aquid Invertebrate Database Bench Sheet Report****Crooked Cr [0804114], Station #2, Sample Date: 10/1/2008 8:44:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

<b>ORDER: TAXA</b>	<b>CS</b>	<b>NF</b>	<b>RM</b>
<b>"HYDRACARINA"</b>			
Acarina	28	4	109
<b>COLEOPTERA</b>			
Dubiraphia		1	16
Ectopria nervosa	-99	2	
Macronychus glabratus			2
Optioservus sandersoni	46	6	
Psephenus herricki	4	1	1
Scirtidae			3
Stenelmis	27	6	
<b>DECAPODA</b>			
Orconectes medius	-99		
Orconectes punctimanus			-99
<b>DIPTERA</b>			
Atherix	3	-99	
Chironomidae	6		
Cricotopus bicinctus	40		3
Cricotopus trifascia	1		
Cricotopus/Orthocladius	70	6	3
Hemerodromia	7		
Natarsia		1	
Nilotanypus	2	1	
Parakiefferiella		2	
Parametriocnemus	3		
Polypedilum convictum	3		
Potthastia	1		
Rheocricotopus	9		
Rheotanytarsus	2		
Simulium	169		
Tabanus	-99	1	
Thienemanniella	1		
Thienemannimyia grp.	1	2	1
Tipulidae	1		
<b>EPHEMEROPTERA</b>			
Acentrella	42	1	
Caenis latipennis	40	245	46
Eurylophella		7	54
Isonychia bicolor	3		1
Tricorythodes	1	4	
<b>HEMIPTERA</b>			

**Aquid Invertebrate Database Bench Sheet Report****Crooked Cr [0804114], Station #2, Sample Date: 10/1/2008 8:44:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

<b>ORDER: TAXA</b>	<b>CS</b>	<b>NF</b>	<b>RM</b>
Microvelia			1
Rhagovelia			1
LEPIDOPTERA			
Petrophila	1		
LIMNOPHILA			
Physella			2
LUMBRICINA			
Lumbricina		-99	-99
MEGALOPTERA			
Corydalus	6		
Nigronia serricornis		1	
ODONATA			
Argia		7	9
Enallagma			3
Gomphus			1
Hagenius brevistylus		6	-99
Helocordulia		-99	
Hetaerina	1		3
Macromia			-99
Stylogomphus albistylus	9	6	1
TRICHOPTERA			
Ceratopsyche morosa grp	25		
Cheumatopsyche	78	1	
Chimarra	6		
Helicopsyche	1		
Hydroptila	1		
Oecetis	1	2	9
Triaenodes			14
TRICLADIDA			
Planariidae	1		
TUBIFICIDA			
Tubificidae			2

**Aquid Invertebrate Database Bench Sheet Report****Crooked Cr [0804115], Station #1, Sample Date: 10/1/2008 11:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

<b>ORDER: TAXA</b>	<b>CS</b>	<b>NF</b>	<b>RM</b>
<b>"HYDRACARINA"</b>			
Acarina	3	4	
<b>AMPHIPODA</b>			
Hyaella azteca		2	24
Stygobromus		1	
<b>BRANCHIOBDELLIDA</b>			
Branchiobdellida	1	6	
<b>COLEOPTERA</b>			
Dubiraphia		7	16
Ectopria nervosa	1		
Hydrophilidae			1
Macronychus glabratus			6
Optioservus sandersoni	11	6	1
Psephenus herricki	14	5	2
Stenelmis	14	7	
<b>DECAPODA</b>			
Orconectes luteus	1	-99	-99
Orconectes medius	1		
Orconectes punctimanus			-99
Orconectes virilis		-99	1
<b>DIPTERA</b>			
Ablabesmyia		4	
Atherix	1		
Ceratopogoninae		3	1
Chironomidae	3	2	2
Corynoneura		1	3
Cricotopus bicinctus	3		7
Cricotopus/Orthocladius	53	7	14
Dicrotendipes			1
Eukiefferiella	1		
Forcipomyiinae		1	
Hemerodromia	2	1	
Labrundinia		1	3
Microtendipes		2	
Nilotanyus	7	1	3
Parakiefferiella	2	5	3
Polypedilum convictum	2	1	
Polypedilum fallax grp			2
Potthastia	20	5	1
Psectrocladius			2



**Aquid Invertebrate Database Bench Sheet Report****Crooked Cr [0804115], Station #1, Sample Date: 10/1/2008 11:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

<b>ORDER: TAXA</b>	<b>CS</b>	<b>NF</b>	<b>RM</b>
Rheocricotopus	1	1	
Rheotanytarsus	1		
Simulium	18		
Stempellinella	2	6	
Stictochironomus		3	
Tabanus	2	-99	
Tanytarsus			3
Thienemanniella	1		1
Thienemannimyia grp.	2	4	6
<b>EPHEMEROPTERA</b>			
Acentrella	74		1
Baetis	102		2
Baetiscidae	1	1	
Caenis latipennis	70	194	170
Eurylophella		2	47
Isonychia bicolor	28		
Procloeon			1
Stenonema femoratum	2	9	
Tricorythodes	9	4	
<b>ISOPODA</b>			
Caecidotea (Blind & Unpigmented)		3	
<b>LIMNOPHILA</b>			
Physella	1	7	1
<b>LUMBRICINA</b>			
Lumbricina	1		
<b>MEGALOPTERA</b>			
Corydalus	1		
<b>MESOGASTROPODA</b>			
Elimia	7	-99	3
<b>ODONATA</b>			
Argia	1	3	1
Boyeria			1
Calopteryx			2
Enallagma			3
Hagenius brevistylus		2	
Hetaerina			4
Stylogomphus albistylus	7	3	1
<b>TRICHOPTERA</b>			
Ceratopsyche morosa grp	27	3	1
Cheumatopsyche	161	3	1

**Aquid Invertebrate Database Bench Sheet Report****Crooked Cr [0804115], Station #1, Sample Date: 10/1/2008 11:30:00 AM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

<b>ORDER: TAXA</b>	<b>CS</b>	<b>NF</b>	<b>RM</b>
Chimarra	1		
Helicopsyche	7		2
Oecetis			7
Oxyethira			2
Polycentropus	3	1	
Triaenodes	1	1	11
<b>TRICLADIDA</b>			
Planariidae	1		

**Aquid Invertebrate Database Bench Sheet Report****Crooked Cr [0930013], Station #1, Sample Date: 4/1/2009 2:30:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

<b>ORDER: TAXA</b>	<b>CS</b>	<b>NF</b>	<b>RM</b>
<b>"HYDRACARINA"</b>			
Acarina	13	15	
<b>AMPHIPODA</b>			
Hyaella azteca			14
<b>BRANCHIOBDELLIDA</b>			
Branchiobdellida			1
<b>COLEOPTERA</b>			
Dubiraphia		1	1
Ectopria nervosa		1	
Helichus lithophilus			2
Optioservus sandersoni	16		
Psephenus herricki	3	2	
Stenelmis	4	2	
<b>DECAPODA</b>			
Orconectes luteus	1		
Orconectes medius	-99	-99	-99
<b>DIPTERA</b>			
Ablabesmyia			1
Atherix	-99		
Ceratopogoninae	2	5	
Chelifera	1		
Clinocera	2		
Corynoneura	7	2	12
Cricotopus bicinctus	12		57
Cricotopus trifascia	13		
Cricotopus/Orthocladius	174	43	91
Eukiefferiella	27	1	2
Hemerodromia	11		
Labrundinia			3
Nilotanyus	6	2	3
Parachaetocladius			1
Parakiefferiella		5	1
Parametriocnemus	38	1	
Phaenopsectra		1	
Polypedilum aviceps	37		1
Polypedilum illinoense grp			1
Potthastia	30	54	16
Psectrocladius			1
Psychoda	1		
Rheocricotopus	42	2	

**Aquid Invertebrate Database Bench Sheet Report****Crooked Cr [0930013], Station #1, Sample Date: 4/1/2009 2:30:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

<b>ORDER: TAXA</b>	<b>CS</b>	<b>NF</b>	<b>RM</b>
Rheotanytarsus	3		
Simulium	53		3
Stempellinella	6	7	1
Tabanus	2	1	
Tanytarsus	1	1	2
Thienemanniella	10	1	2
Thienemannimyia grp.	9	39	4
Tipula	-99		
<b>EPHEMEROPTERA</b>			
Acentrella	55		1
Baetis	2		
Caenis latipennis	11	56	10
Eurylophella enoensis		1	12
Stenonema femoratum		1	
<b>LIMNOPHILA</b>			
Physella			5
<b>LUMBRICINA</b>			
Lumbricina	1	-99	
<b>MEGALOPTERA</b>			
Corydalus	-99		
<b>MESOGASTROPODA</b>			
Elimia	-99	2	21
<b>ODONATA</b>			
Argia		1	
Boyeria			1
Calopteryx			2
Gomphidae	1		
Stylogomphus albistylus		4	
<b>PLECOPTERA</b>			
Amphinemura	18		
Leuctridae	25	33	
Perlesta	6		
Pteronarcys pictetii	5		
<b>TRICHOPTERA</b>			
Ceratopsyche morosa grp	8		
Cheumatopsyche	49	-99	
Chimarra	3		
Helicopsyche	5		6
Hydroptila	5		
Oecetis		1	

**Aquid Invertebrate Database Bench Sheet Report****Crooked Cr [0930013], Station #1, Sample Date: 4/1/2009 2:30:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

<b>ORDER: TAXA</b>	<b>CS</b>	<b>NF</b>	<b>RM</b>
Polycentropus		1	1
Pycnopsyche			-99
Triaenodes			7
TRICLADIDA			
Planariidae	1		

**Aquid Invertebrate Database Bench Sheet Report****Crooked Cr [0930014], Station #2, Sample Date: 4/1/2009 3:30:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

<b>ORDER: TAXA</b>	<b>CS</b>	<b>NF</b>	<b>RM</b>
<b>"HYDRACARINA"</b>			
Acarina	35	11	2
<b>COLEOPTERA</b>			
Dubiraphia	1	3	8
Ectopria nervosa	1		
Microcylloepus pusillus			1
Optioservus sandersoni	3		
Psephenus herricki	1	-99	
Stenelmis	13	8	
<b>DECAPODA</b>			
Orconectes punctimanus		-99	
<b>DIPTERA</b>			
Antocha	1		
Atherix		-99	
Brillia			1
Ceratopogoninae	2	2	2
Chironomidae	5	3	5
Clinocera	7	1	
Corynoneura	7	11	14
Cricotopus bicinctus	78	8	69
Cricotopus trifascia			1
Cricotopus/Orthocladius	175	84	81
Dicrotendipes		1	
Diptera		5	
Dixella			3
Hemerodromia	1		1
Hydrobaenus	2	13	
Labrundinia			1
Myxosargus		1	
Nilotanypus	8	1	2
Parakiefferiella	25	25	9
Paramerina			1
Parametriocnemus	15	1	5
Polypedilum aviceps	1		
Polypedilum illinoense grp			2
Potthastia	55	19	4
Psectrocladius		3	
Rheocricotopus	20	2	9
Rheotanytarsus	2		1
Simulium	9		11

**Aquid Invertebrate Database Bench Sheet Report****Crooked Cr [0930014], Station #2, Sample Date: 4/1/2009 3:30:00 PM****CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

<b>ORDER: TAXA</b>	<b>CS</b>	<b>NF</b>	<b>RM</b>
Stempellinella		1	
Tabanus	2	-99	
Thienemanniella	4	2	
Thienemannimyia grp.	29	11	19
Tipula			1
Zavrelimyia			1
<b>EPHEMEROPTERA</b>			
Acentrella	15		1
Baetis	1		
Caenis latipennis	70	86	39
Centroptilum			1
Eurylophella enoensis	-99	3	10
<b>LIMNOPHILA</b>			
Physella	2	1	3
<b>LUMBRICINA</b>			
Lumbricina	-99	-99	
<b>MEGALOPTERA</b>			
Nigronia serricornis		-99	
<b>ODONATA</b>			
Argia		1	3
Enallagma			1
Gomphidae	4	4	1
Hetaerina			5
Stylogomphus albistylus		-99	1
<b>PLECOPTERA</b>			
Amphinemura			1
Isoperla	1		
Perlesta			1
Pteronarcys pictetii			-99
<b>TRICHOPTERA</b>			
Ceratopsyche morosa grp	1		
Cheumatopsyche	5	1	1
Helicopsyche	4		1
Hydroptila	3		
Oecetis			4
Polycentropus	3	-99	
Pycnopsyche			-99
Trienodes			4
<b>TUBIFICIDA</b>			
Enchytraeidae	2	1	1

**Aquid Invertebrate Database Bench Sheet Report**

**Crooked Cr [0930014], Station #2, Sample Date: 4/1/2009 3:30:00 PM**

**CS = Coarse; NF = Nonflow; RM = Rootmat; -99 = Presence**

<b>ORDER: TAXA</b>	<b>CS</b>	<b>NF</b>	<b>RM</b>
Tubificidae		1	